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Torque and EMG in rotation extension of the torso from pre-rotated and flexed postures

Shrawan Kumar *, Yogesh Narayan

Department of Physical Therapy, University of Alberta, Edmonton, Alta., Canada T6G 2G4

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Abstract

Background. Back injury is a common place in our society. Up to two-thirds of back injuries have been associated with trunk rotation. However, the torque production ability with a rotated spine and electromyographic activity of trunk muscles in such efforts is poorly understood. Therefore, the objectives of this study are to study torque production capacity of variously rotated and flexed trunk and to measure the EMG of selected trunk muscles in these activities.

Methods. Nineteen normal young subjects (7 males and 12 females) were recruited. Subjects were stabilized on a posture-stabilizing platform and were instructed to assume a flexed and right rotated posture (20°, 40° and 60° of rotation and 20°, 40° and 60° of flexion) in a random order. The subjects were asked to exert their maximal voluntary contraction in the asymmetric plane of rotation–extension for a period of 5 s. The surface EMG of the external and internal obliques, rectus abdominis, latissimus dorsi, erector spinae at the 10th thoracic and 3rd lumbar vertebral levels was recorded bilaterally along with the torque generated.

Findings. Whereas the torque generated was significantly affected by both rotation and extension in both genders ($P < 0.001$), the EMG was independent of rotation but affected by flexion in females only ($P < 0.01$). The torques produced by both genders in each of the nine postures was significantly different from each other ($P < 0.001$). The EMG demonstrated a trend of increase with increasing rotation and flexion. The response surfaces of normalized peak EMG of the right external oblique and internal oblique was somewhat similar, indicating a rotator torque and a stabilizing effect. The left latissimus dorsi and right external oblique provided the rotational torque and the right erector spinae provided the extensor effort. Since the rotation–extension was performed in the plane of asymmetry, the effort required the recruitment of muscles involved in left rotation, stability of rotated spine and an extensor effort.

Interpretation. The torque production capacity of the human trunk is posture dependent and declines with increasing rotation. However, with increasing rotation and flexion, the magnitude of EMG increases. This implies that with increasing asymmetry, it requires more muscle effort (thus tissue stress) to generate less torque. Increasing asymmetry tends to weaken the system and may enhance chances of injury.

Keywords: Trunk rotation; EMG; Rotation–extension; Spinal mechanics

1. Introduction

Information on mechanics of rotation–extension as well as the mechanism of development of rotary torque is sparse. The phasic relationship as well as relative quantitative activity of different muscles is not entirely clear or complete. Though it is known that both abdominal and dorsal muscles are involved in development of axial torque (McGill, 1991; Marras and Mirka, 1992; Kumar, 1996, 2004; Kumar et al., 2002a,b), the initiation of extension in a rotated posture and its stabilization is still unclear. In axial rotation the agnostic muscles fired up to 300 ms earlier than some of the antagonistic muscles (Kumar et al., 1996). The agnostic muscles were responsible for 65% of the total gross EMG output; whereas, antagonistic muscles were responsible for 35% of the gross EMG output. The slopes of the muscle activities during onset and offset

* Corresponding author.
E-mail address: shrawan.kumar@ualberta.ca (S. Kumar).

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periods were biphasic with significant difference. Kumar et al. (1996, 2002a,b) concluded that the axial rotation is achieved by activities of the contralateral external obliques and ipsilateral latissimus dorsi constituting a force couple with spine acting as a fulcrum. The erectors spinae, however, increased their activity only modestly with increasing magnitude of contraction contributing to spinal stability. The trunk returned to the neutral position after rotational displacement due to elastic recoil controlled by the same agnostic muscles (Kumar et al., 1996). A range of 10–15° of axial rotation on either side of the sagittal axis required very little muscle effort, producing a shallower slope of EMG. Only when the passive resistance increased significantly that the slope of EMG response had a steeper slope.

The current knowledge remains obscure in delineation of the role of abdominal and dorsal muscles in execution, magnitude of contribution, phasic relationship, and also the extent of synergism and antagonism of different spinal muscles during simultaneous trunk twisting and bending activities. However, Lee et al. (2006) have reported differential activation of deep and superficial muscles (longissimus thoracis and multifidus) in posterior paraspinal muscles due to their different primary roles. They concluded that the multifidus was responsible for coupling axial rotation and lateral flexion. In isometric axial rotation, from the neutral posture, the phasic relationship of the external oblique, latissimus dorsi and the erectors spinae were different from all dorsal and ventral muscles studied. The activation of the contralateral external oblique preceded that of the ipsilateral latissimus dorsi, followed by the erectors spinae (Kumar et al., 2002a). While the magnitude of the external oblique and the latissimus dorsi continued to increase with the increasing intensity of contraction, the erector spinae showed only small increases. (Kumar et al., 2002b) reported that the rotational efforts in the direction of pre-rotation generated significantly higher EMG, even with a significant reduction in torque.

While the muscle recruitment in symmetric extension is well known, it is unclear as to how these muscles behave in rotation–extension. It is unclear whether the entire extensor effort is mounted by the erector spinae of the right and left sides equally or the direction of rotation modifies this behaviour. Further, whether the latissimus dorsi acts synergistically sharing the load or they remain unaffected by the extensor effort and contribute only to the rotary component. In order to answer these questions an experiment was conducted where normal subjects of both genders assumed flexed postures to the extent of 20°, 40° and 60° and rotation to right also by 20°, 40° and 60° from where they performed their maximal voluntary rotation–extension in the plane of rotation. While the subjects performed these activities the EMG of their dorsal and ventral muscles were recorded along with the torque generated. The following muscles were studied bilaterally: external oblique, internal oblique, rectus abdominis, erector spinae at T10 and L3, and latissimus dorsi. The objectives of the study were:

1. To measure the torque generated in each of the rotation–extension effort from nine postures of male and female experimental samples.
2. To measure the magnitude of the EMG of the trunk muscles during trunk rotation–extension in maximal isometric contraction at various degrees of asymmetries (20°, 40° and 60° of twisting at 20°, 40° and 60° of flexion).

2. Methods

2.1. Sample

Nineteen normal young subjects (7 males and 12 females) volunteered for the study. The mean (standard deviation) age, height and weight of the male and female samples were 23 years (4 years), 176.9 cm (4 cm), 72.5 kg (6 kg) and 21 years (3 years), 167 cm (6.3 cm) and 58.8 kg (5.6 kg), respectively. Low-back pain within the past year requiring one-week vocational absence, generalized musculoskeletal disorders, neuromuscular disorders, spinal and abdominal surgeries was used as exclusion criteria. Ethics approval was granted for the project and informed consent forms were signed by all subjects.

2.2. Experimental set-up

The trunk rotation–extension efforts were measured using the Static & Dynamic Strength Tester (Kumar and Garand, 1992). These tests were done with equipment in an isometric locked position. The force exerted was measured by the load cell of the SDST (Interface Model SM 500, 500 lb maximum with a natural frequency of 1.5 kHz, Interface Technology, Arizona, USA). The load cell of the Static & Dynamic Strength Tester was connected with the chest harness of the subject through a flexible inextensible airplane steel cable. The harness consisted of adjustable, snugly fitting, rigid bands with an eyehook at the front for connecting the cable.

The posture stabilizing platform consisted of a horizontal circular plate mounted with two oil pipes as uprights (Fig. 1). Slid over these uprights were three height-adjustable belts to fasten the lower extremities of the subject, who stood on the circular plate. This plate was mounted on a rectangular base plate, so that it could revolve like a turntable on rigidly installed castors, but could be clamped in any position. Using this mechanism, the platform could be arranged in 20°, 40° and 60° of rotation with respect to the sagittal plane, causing the flexible but inextensible cable to be aligned along a plane intersecting the sagittal plane at 20°, 40° and 60° angles as adjusted. Since the extension was instructed to be in the plane of the cable, all efforts were in 20°, 40° and 60° rotations with respect to the sagittal plane. The posture stabilizing platform was rigidly attached to the Static & Dynamic Strength Tester, leveled with it at one end and fixed to the wall on the other to achieve a rigid